MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 1, 2019/2020

ETN3136 – DIGITAL COMMUNICATIONS

(TE)

25 OCTOBER 2019
9:00 A.M – 11:00 A.M
(2 Hours)

INSTRUCTIONS TO STUDENTS

1. This question paper consists of 7 pages including cover page with 4 Questions only.

2. Attempt **ALL FOUR** questions. All questions carry equal marks and the distribution of the marks for each question is given.

3. Please write all your answers in the Answer Booklet provided.

Question 1

(a) (i) State four design concerns of a digital communication system.

[4 marks]

(ii) Describe the main difference between digital and analogue sources.

[2 marks]

(b) Both analogue and digital signals can be classified into three categories depending on their signal characteristics. State and briefly describe these categories.

[6 marks]

(c) Explain the meaning of cross-correlation and autocorrelation of a signal. How is autocorrelation related to power spectral density?

[3 marks]

(d) (i) A linear time invariant system needs to satisfy the *superposition principle* and has to be *time invariant*. Explain these two conditions with the help of suitable diagrams, if necessary.

[6 marks]

(ii) Describe the two requirements for a linear time invariant system to have output with no distortion.

[2 marks]

(iii) Given that a digital communication system is required to transmit at a capacity, $C = 3.7$ kbps. Its signal-to-noise ratio, SNR = 12. Calculate the bandwidth, B that is required in order to achieve this.

[2 marks]

Continue...

Question 2

(a) In digital communication, sampling is one of the key step to convert analogue signal to digital signal. For that, the Nyquist sampling theorem must not be violated.

(i) Briefly describe the Nyquist sampling theorem.

[2 marks]

(ii) A message signal with spectrum $G(f)$ and maximum frequency f_M is shown in Figure Q2(a). While, the envelope of a sinc function is shown in Figure Q2(b). The sampling frequency is f_S. Assume that the Nyquist sampling theorem is not violated. Sketch on top of Figure Q2(b) the spectrum of the sampled message signal of $G(f)$ for the case of instantaneous sampling, natural sampling and flat-top sampling (i.e., 3 separate sketches altogether).

[9 marks]

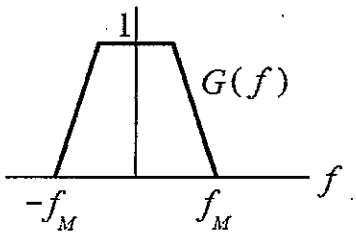

Figure Q2(a)

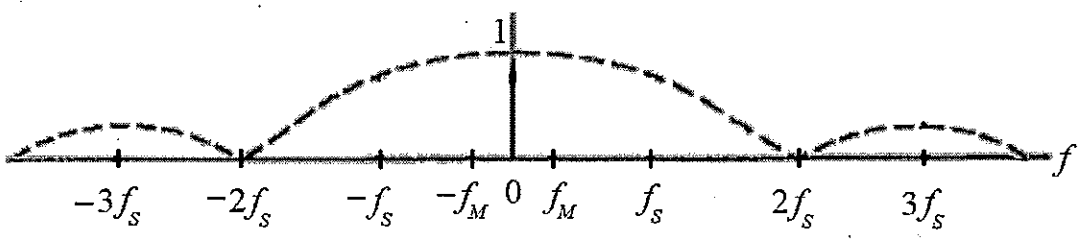

Figure Q2(b)

(b) (i) With a suitable diagram that includes a comparator, quantizer and accumulator, explain the working principles of Delta Modulation.

[9 marks]

(ii) Given that a sine wave has frequency f_m and amplitude A_m. This sine wave acts as an input to a Delta Modulator with step size Δ. Given also the sampling period is T_s. Show that slope overload will occur if $Am > \frac{\Delta}{2\pi f_m T_s}$.

[5 marks]

Continue...

Question 3

(a) Given a binary stream of 0101011100. Draw the waveform corresponding to this binary stream for the following line codes.

(i) Unipolar non return-to-zero (NRZ).

[1 mark]

(ii) Polar NRZ.

[1 mark]

(iii) Unipolar return-to-zero (RZ).

[1 mark]

(b) Let $h_e(t)$ and $H_e(f)$ be the effective impulse response and its transfer function of a communication system, respectively. Also, let T_s be the symbol period.

(i) According to Nyquist's first method, what is the condition for $h_e(t)$ at every T_s duration?

[2 marks]

(ii) Suggest a suitable shape for $h_e(t)$ and $H_e(f)$ that satisfies Nyquist's first method. Write down the mathematical expression for your $h_e(t)$ and $H_e(f)$.

[4 marks]

(iii) Sketch $h_e(t)$ in Q3(b)(ii). Label the sampling instants in your sketch.

[2 marks]

(iv) Sketch $H_e(f)$ in Q3(b)(ii). What is the name given to the bandwidth of $H_e(f)$?

[2 marks]

(c) Data is to be sent at a bit rate of 20 Mbits/s over a telecommunication channel having bandwidth of 15 MHz. Assume that QPSK modulation is used.

(i) Calculate the required roll-off factor, r of the raised cosine filter.

[2 marks]

(ii) The modulation is then changed to 16-PSK. With the roll-off factor in Q3(c)(i), calculate the required channel bandwidth, assuming that data is still sent at bit rate of 20 Mbits/s.

[2 marks]

(d) Multiple access schemes are used to increase the efficiency of resource utilization in digital communication systems. Briefly describe the working principals of the following multiple access schemes.

(i) Spread spectrum.

[4 marks]

(ii) Orthogonal frequency division multiplexing.

[4 marks]

Continue...

Question 4

(a) Consider a direct sequence binary phase-shift keying (DS/BPSK) system. To generate the pseudo noise (PN) sequence, the DS/BPSK system uses feedback shift registers of length $m = 31$. Given that the bit error probability, $P_e = Q\left(\sqrt{\frac{2E_b}{N_o}}\right)$ and must be at least 10^{-5}. Refer to Appendix I for Q-function table, if necessary.

(i) Calculate the processing gain in decibels.

[2 marks]

(ii) Calculate the anti-jam margin in decibels.

[5 marks]

(b) Given that a non-return-to-zero (NRZ) on-off transmission has error probability, $P_e = \frac{1}{2}\left[1 - \text{erf}\left(\frac{A}{2\sqrt{2}\sigma}\right)\right]$ where A is the signal amplitude and σ is the noise root mean square (rms) value. Refer to Appendix I for Q-function table, if necessary.

(i) Rewrite P_e in terms of the Q-function.

[2 marks]

(ii) Calculate P_e when the signal amplitude, A is double the noise rms value, σ.

[3 marks]

(iii) Find the signal-to-noise ratio, $\frac{A}{\sigma}$ in order to achieve error probability, $P_e = 10^{-5}$.

[3 marks]

(c) A matched filter (MF) is used to maximize the receiver's output signal-to-noise ratio.

(i) What is the relationship between the input signal and the MF's impulse response?

[2 marks]

(ii) Describe the working principles of the integrate-and-dump circuit implementation of a MF.

[4 marks]

(iii) Figure Q4(c) shows the input waveform, $x(t)$ with bit period, T. Sketch the output waveform of the MF, as well as, the output waveform of the integrate-and-dump circuit.

[4 marks]

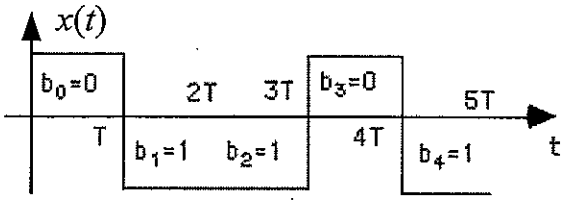

Figure Q4(c)

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Appendix I

Tabulated values of Q-function

The Q Function (Gaussian Distribution with $\mu = 0$ and $\sigma = 1$)

$$Q(a) = \int_a^\infty \frac{1}{\sqrt{2\pi}} e^{\frac{-x^2}{2}} dx \qquad Q(a) \cong \frac{1}{a\sqrt{2\pi}} e^{\frac{-a^2}{2}} \text{ for } a \geq 3$$

	3rd Significant Digit									
a	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	0.5000	0.4960	0.4920	0.4880	0.4840	0.4801	0.4761	0.4721	0.4681	0.4641
0.1	0.4602	0.4562	0.4522	0.4483	0.4443	0.4404	0.4364	0.4325	0.4286	0.4247
0.2	0.4207	0.4168	0.4129	0.4090	0.4052	0.4013	0.3974	0.3936	0.3897	0.3859
0.3	0.3821	0.3783	0.3745	0.3707	0.3669	0.3632	0.3594	0.3557	0.3520	0.3483
0.4	0.3446	0.3409	0.3372	0.3336	0.3300	0.3264	0.3228	0.3192	0.3156	0.3121
0.5	0.3085	0.3050	0.3015	0.2981	0.2946	0.2912	0.2877	0.2843	0.2810	0.2776
0.6	0.2743	0.2709	0.2676	0.2643	0.2611	0.2578	0.2546	0.2514	0.2483	0.2451
0.7	0.2420	0.2389	0.2358	0.2327	0.2297	0.2266	0.2236	0.2207	0.2177	0.2148
0.8	0.2119	0.2090	0.2061	0.2033	0.2005	0.1977	0.1949	0.1922	0.1894	0.1867
0.9	0.1841	0.1814	0.1788	0.1762	0.1736	0.1711	0.1685	0.1660	0.1635	0.1611
1.0	0.1587	0.1562	0.1539	0.1515	0.1492	0.1469	0.1446	0.1423	0.1401	0.1379
1.1	0.1357	0.1335	0.1314	0.1292	0.1271	0.1251	0.1230	0.1210	0.1190	0.1170
1.2	0.1151	0.1131	0.1112	0.1094	0.1075	0.1057	0.1038	0.1020	0.1003	0.0985
1.3	0.0968	0.0951	0.0934	0.0918	0.0901	0.0885	0.0869	0.0853	0.0838	0.0823
1.4	0.0808	0.0793	0.0778	0.0764	0.0749	0.0735	0.0721	0.0708	0.0694	0.0681
1.5	0.0668	0.0655	0.0643	0.0630	0.0618	0.0606	0.0594	0.0582	0.0571	0.0559
1.6	0.0548	0.0537	0.0526	0.0516	0.0505	0.0495	0.0485	0.0475	0.0465	0.0455
1.7	0.0446	0.0436	0.0427	0.0418	0.0409	0.0401	0.0392	0.0384	0.0375	0.0367
1.8	0.0359	0.0351	0.0344	0.0336	0.0329	0.0322	0.0314	0.0307	0.0301	0.0294
1.9	0.0287	0.0281	0.0274	0.0268	0.0262	0.0256	0.0250	0.0244	0.0239	0.0233
2.0	0.0228	0.0222	0.0217	0.0212	0.0207	0.0202	0.0197	0.0192	0.0188	0.0183
2.1	0.0179	0.0174	0.0170	0.0166	0.0162	0.0158	0.0154	0.0150	0.0146	0.0143
2.2	0.0139	0.0136	0.0132	0.0129	0.0125	0.0122	0.0119	0.0116	0.0113	0.0110
2.3	0.0107	0.0104	0.0102	0.0099	0.0096	0.0094	0.0091	0.0089	0.0087	0.0084
2.4	0.0082	0.0080	0.0078	0.0075	0.0073	0.0071	0.0069	0.0068	0.0066	0.0064
2.5	0.0062	0.0060	0.0059	0.0057	0.0055	0.0054	0.0052	0.0051	0.0049	0.0048
2.6	0.0047	0.0045	0.0044	0.0043	0.0041	0.0040	0.0039	0.0038	0.0037	0.0036
2.7	0.0035	0.0034	0.0033	0.0032	0.0031	0.0030	0.0029	0.0028	0.0027	0.0026
2.8	0.0026	0.0025	0.0024	0.0023	0.0023	0.0022	0.0021	0.0021	0.0020	0.0019
2.9	0.0019	0.0018	0.0018	0.0017	0.0016	0.0016	0.0015	0.0015	0.0014	0.0014
3.0	0.0014	0.0013	0.0013	0.0012	0.0012	0.0011	0.0011	0.0011	0.0010	0.0010
3.1	0.0010	0.0009	0.0009	0.0009	0.0008	0.0008	0.0008	0.0008	0.0007	0.0007
3.2	0.0007	0.0007	0.0006	0.0006	0.0006	0.0006	0.0006	0.0005	0.0005	0.0005
3.3	0.0005	0.0005	0.0005	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0003
3.4	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0002

$Q(a)$	a
10^{-4}	3.73
5×10^{-5}	3.90
10^{-5}	4.27
5×10^{-6}	4.43

$Q(a)$	a
10^{-6}	4.76
10^{-7}	5.20
10^{-8}	5.61
10^{-9}	6.00

Continue...

Appendix II

Fourier Transform Operations

Operation	$g(t)$	$G(\omega)$
Addition	$g_1(t)+g_2(t)$	$G_1(\omega)+G_2(\omega)$
Scalar multiplication	$kg(t)$	$kG(\omega)$
Symmetry	$G(t)$	$2\pi g(-\omega)$
Scaling	$g(at)$	$\frac{1}{\lvert a\rvert}G\left(\frac{\omega}{a}\right)$
Time shift	$g(t-t_o)$	$G(\omega)e^{-j\omega t_o}$
Frequency shift	$g(t)e^{j\omega_o t}$	$G(\omega-\omega_o)$
Time convolution	$g_1(t)*g_2(t)$	$G_1(\omega)G_2(\omega)$
Frequency convolution	$g_1(t)g_2(t)$	$\frac{1}{2\pi}G_1(\omega)*G_2(\omega)$
Time differentiation	$\frac{d^n g}{dt^n}$	$(j\omega)^n G(\omega)$
Time integration	$\int_{-\infty}^{t} g(x)dx$	$\frac{G(\omega)}{j\omega}+\pi G(0)\delta(\omega)$

End of Paper